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U.S. Energy Flow—1999

Gina V. Kaiper

March 2001

U.S. Department of Energy

Lawrence
Livermore
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Laboratory

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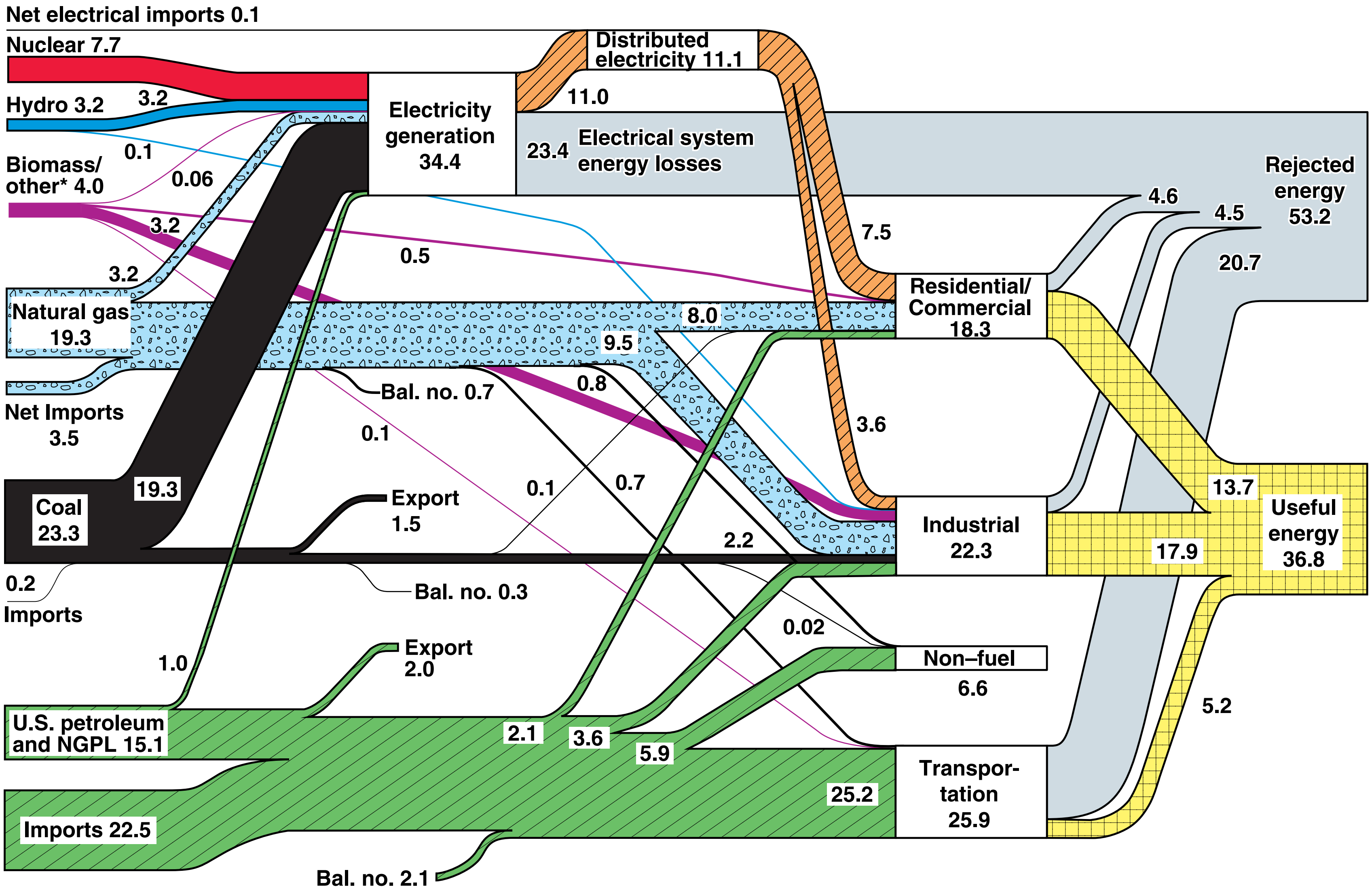
Net Primary Resource Consumption 97 Quads



Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 1999*
*Biomass/other includes wood and waste, geothermal, solar, and wind.

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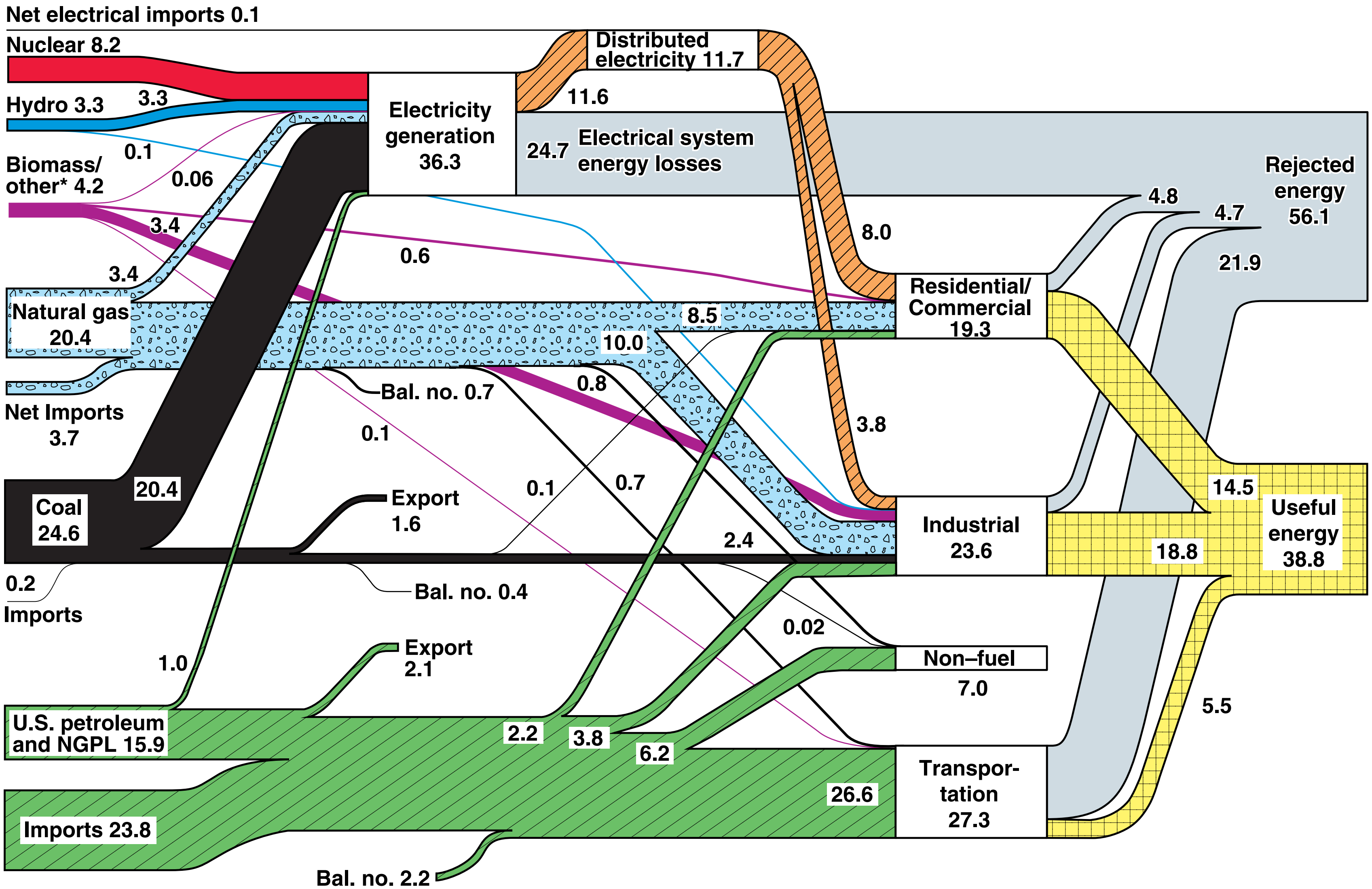
U.S. Energy Flow – 1999
Net Primary Resource Consumption 102 Exajoules



Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 1999*
*Biomass/other includes wood and waste, geothermal, solar, and wind.

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Notes on the U.S. Energy Flow Chart for 1999

General Notes

Background

Lawrence Livermore National Laboratory (LLNL) has prepared similar flow charts of U.S. energy consumption since 1972. The chart follows the flow of individual fuels and compares these on the basis of a common energy unit of quadrillion British thermal units (Btu). A quadrillion, or "quad," is 10^{15}. One Btu is the quantity of heat needed to raise the temperature of 1 pound of water by 1°F at or near 39.2°F.

The width of each colored line across this chart is in proportion to the amount of quads conveyed. (Exception: lines showing extremely small amounts have been made wide enough to be clearly visible.)

In most cases, the numbers used in this chart have been rounded to the nearest tenth of a quad, although the original data was published in hundredths or thousandths of a quad. As a consequence of independent rounding, some of the summary numbers may not appear to be a precise total of their various components.

The first chart in this document uses quadrillion Btu's to conform with data from the U.S. Department of Energy's Energy Information Administration (EIA). However, the second chart is expressed in exajoules. A joule is the metric unit for heat. One Btu equals 1,055.06 joules; and one quadrillion Btu's equals 1.055 exajoules (an exajoule is 10^{18} joules).

Data Sources

The chart incorporates production and end-use data compiled by the Energy Information Administration, as published in the EIA's *Annual Energy Review 1999* [DOE/EIA-0384(99), Washington, D.C., July 2000]. This report is available on the Web at http://www.eia.doe.gov/aer .

In the *Annual Energy Review 1999* (AER99), summary data on energy production, imports, exports, and consumption is provided in Diagram 1, "Energy Flow, 1999" (p. 3) and Table 1.1., "Energy Overview, 1949–1999" (p. 5). These show that 96.60 quads of energy were consumed in the United States in 1999.

Table 1.2, "Energy Production by Source, 1949–1999" (AER99, p. 7) gives additional details about the 72.523 quads of energy produced within the United States.

Table 1.3, "Energy Consumption by Source, 1949–1999" (AER99, p. 9) indicates the amounts of various fossil fuels and renewable energy sources consumed, as well as nuclear energy.

Table 1.4, "Energy Imports, Exports, and Net Imports, 1949–1999" (AER99, p. 11) shows that the United States had net energy imports of 23.10 quads in 1999. (Note that this represents about 24% of total energy consumed and that petroleum accounts for about 89% of U.S. imported energy.)

Table 2.1, “Energy Consumption by End-Use Sector, 1949–1999” (AER99, p. 37) gives the amounts and types of energy consumed by the three end-use sectors: (1) Residential / Commercial, (2) Industrial, and (3) Transportation.

End-Use Sectors

The ***Residential/Commercial*** sector includes private and institutional residences; business establishments not engaged in transportation or manufacturing; commercial establishments; religious and nonprofit organizations; health, social, and educational institutions; and federal, state, and local governments. Electricity used for public street and highway lighting is also included.

The ***Industrial*** sector includes manufacturing industries (the largest part of the sector), mining, construction, agriculture, fisheries, and forestry. Establishments range from large steel mills to small farms. In LLNL’s energy flow chart, fossils fuels used by industry in a non-fuel capacity have been treated as a separate data stream; however, most of the AER99 tables incorporate non-fuel consumption in the data for the industrial sector.

The ***Transportation*** sector includes all types of public and private vehicles that transport people and commodities. This sector also includes the energy used to transport natural gas in pipelines.

Energy Content

The energy flow chart shows all energy streams in terms of a common energy unit: quadrillion Btu. The EIA typically uses conversion factors that represent the gross heat content of the fuel, which is the total amount of heat released when fuel is burned (i.e., the “higher heating value”).

Appendix A of AER99 (pp. 327–337) gives the thermal conversion factors used in that report. These factors are computed annually from the best available data, weighted as appropriate. The heat content depends on source, type, year of production, and use of fuel. For example, the relatively small amount of coal consumed by the residential / commercial sector has an average heat content of approximately 22.783 million Btu per short ton of coal, but the coal used to generate electricity has an average heat content of approximately 20.479 million Btu per short ton. (AER99, T. A5, p. 331).

Some conversion factors, useful for estimation, include:

Fuel	***Energy content (Btu)***
Short ton of coal	21,400,000
Barrel (42 gallons) of crude oil	5,800,000
Cubic foot of natural gas	1,027
Kilowatt-hour of electricity	3,412

Conversion Efficiency Factors

For the sake of consistency with LLNL’s previous energy flow charts, the U.S. chart for 1999 assumes the same conversion efficiencies as in previous years to determine the proportion of “useful” to “rejected” energy.

For electricity generation, losses are assumed to be about two-thirds of the energy consumed. The energy flow chart for 1999 shows “electrical system energy losses” of 23.4 quads, as given in Table 2.1 of AER99 (p. 37). This includes the amount of energy lost during the generation, transmission, and distribution of electricity, including plant and unaccounted-for uses (AER99, p. 357). Transmission and distribution losses, which are not spelled out separately on this chart, are estimated to be about 9% of the gross generation of electricity.

For the residential/commercial sector, we have again assumed an efficiency of 75%. This is a weighted average between space heating at approximately 60% efficiency and motors and other electrical uses at about 90% efficiency.

For the industrial sector, we have continued to assume a conversion efficiency of 80%.

For transportation, we assume a generous 20% efficiency, which corresponds to the approximate efficiency of the internal combustion engines as measured on Federal Driving Schedules.

Balancing Numbers

For visual clarity, the 1999 energy flow chart eliminates some of the smaller lines that appeared in previous versions (e.g., storage, stocks, and strategic reserve amounts, as well as field use of natural gas.) Instead, three “balancing numbers” have been indicated, which together add about 1 quad of energy between the left-hand (or “production”) side of the chart and the right-hand (or “consumption”) side. This corresponds approximately to the 0.98 quad “adjustments” amount given in AER99 on Diagram 1 (p. 3) and Table 1.1 (p. 5).

Electricity Generation

LLNL’s earlier energy flow charts had separate lines for “utility consumption of electricity” and “cogeneration.” This 1999 version does not distinguish between utility and nonutility generation.

The nonutility power producers include cogenerators who provide both electricity and steam or heat for industrial or other purposes. In addition, nonutility power producers include small power producers (which use renewables for at least 75% of their output) and independent power producers (which are unaffiliated with franchised utilities, do not possess transmission facilities, and do not sell power in the retail service area where they have a franchise).

Diagram 5 in AER99 (p. 209) shows the very complicated electricity flow of both electric utilities and nonutility power producers. This diagram shows net generation of 10.86 quads by the utilities and 1.69 quads by the nonutility power producers—thus 13% of the net electricity generated in the United States in 1999 came from nonutility power producers. The nonutilities made direct use of 0.46 quads of this electricity but sold 0.85 quads to the utilities, where it became part of the 11.1 quads of electricity sold to the end-user sectors.

Nonfuel Use

The data on fossil fuel consumption for nonfuel use is from AER, Table 1.15 (p. 33). Petroleum products account for 5.85 quads of nonfuel use and include asphalt and road oil, liquefied petroleum gases, pentanes plus, lubricants, petrochemical feedstocks, special naphthas, and other products.

Nonfuel consumption in 1999 accounted for 6.9% of the primary energy resources consumed in the United States; however, because these resources were not used for energy purposes, LLNL’s energy flow chart does not assign “rejected” and “useful” designations.

Notes on Primary Resources

Biomass/Other

By far the largest portion in this category comes from "wood and waste," which accounted for 3.514 quads of energy produced in 1999. Geothermal energy accounted for 0.327 quads; solar for 0.076 quads; and wind for 0.038 quads. (AER99, Table 1.2, p. 7).

Coal

In 1999, coal represented almost a third of the energy produced within the United States. About 90% of U.S. coal consumption went for the generation of electricity and fueled about 58% of the United States' generation of electricity.

More details about the production and consumption of coal are given in AAER99 in Diagram 4 (p. 189) and Table 7.1 (p. 191). The approximate heat content of coal is given in Table A5 (p. 331).

Hydroelectric Power

This involves the production of power from falling water. Almost all of this energy goes for the generation of electricity, although a tiny fraction (about 0.1 quad) goes directly into industrial consumption.

Natural Gas

In AER99, details about natural gas production and consumption are included in Diagram 3 (p. 167) and Table 6.1 (p. 169). The approximate heat content of natural gas is given in Table A4 (p. 330).

Net imports of natural gas in 1999 amounted to 3.48 quads and accounted for about 15.8% of the natural gas consumed in the United States (AER99, Table 6.3, p. 173). About 94% of the gross natural gas imports came from Canada.

Of the natural gas withdrawn from U.S. wells in 1999, about 22% came from offshore locations (AER99, Table 6.4, p 175).

Nuclear Energy

This is generated by the 104 operable nuclear generating units in the United States. Nuclear energy accounted for 19.8% of electricity net generation in the United States in 1999 (AER99, Table 9.2, p. 247).

Petroleum and NGPL

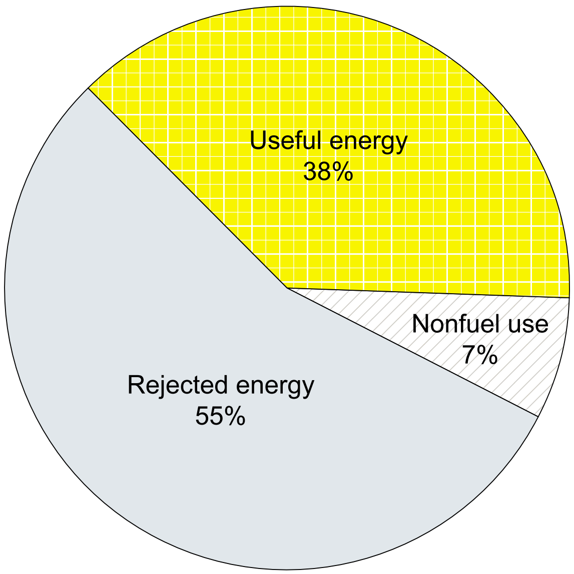
This category includes both crude oil and natural gas plant liquids (i.e., hydrocarbons in natural gas that have been separated as liquids). In AER99, details about petroleum are found in Diagram 2 (p. 117) and Tables 5.1 (p. 119). The approximate heat content of various petroleum products and of crude oil and NGPL can be found in AER99, Tables A1, A2, and A3 (pp. 327–329).

Petroleum, at 37.7 quads, accounted for 39% of the United States' 1999 energy consumption. Motor gasoline was 43% of the total petroleum products supplied in 1999 (AER99, Fig. 5.11, p. 138).

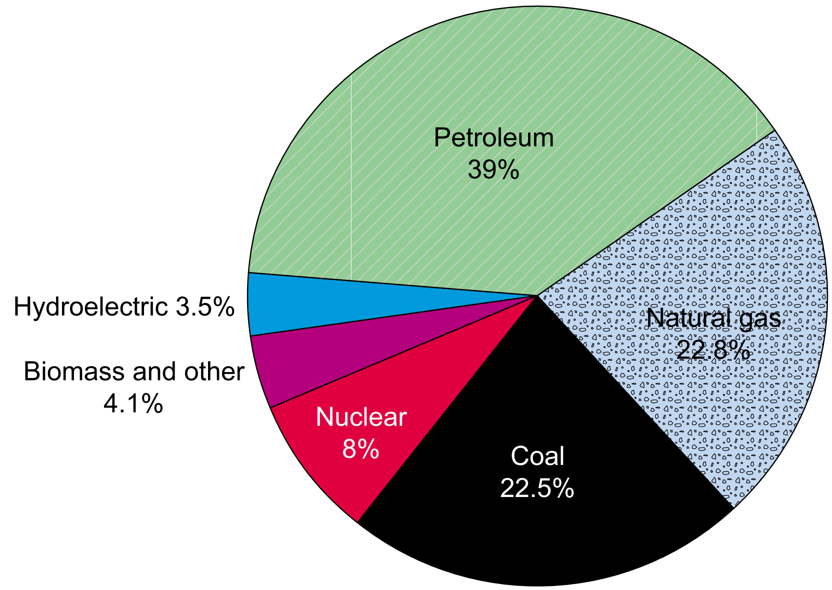
The net petroleum imports of 20.6 quads accounted for about 55% of the 37.7 quads of petroleum consumed in 1999. By comparison, in 1990 only about 46% of petroleum consumed came from imports. During that same interval (1990 to 1999), total U.S. energy consumption increased almost 15% (84.2 quads to 96.6 quads), but petroleum consumption increased only about 12% (33.6 quads to 37.7 quads). (AER99, Tables 1.3 and 1.4)

Other Ways to View This Data

The U.S. Consumed 96.6 Quads of Energy in 1999

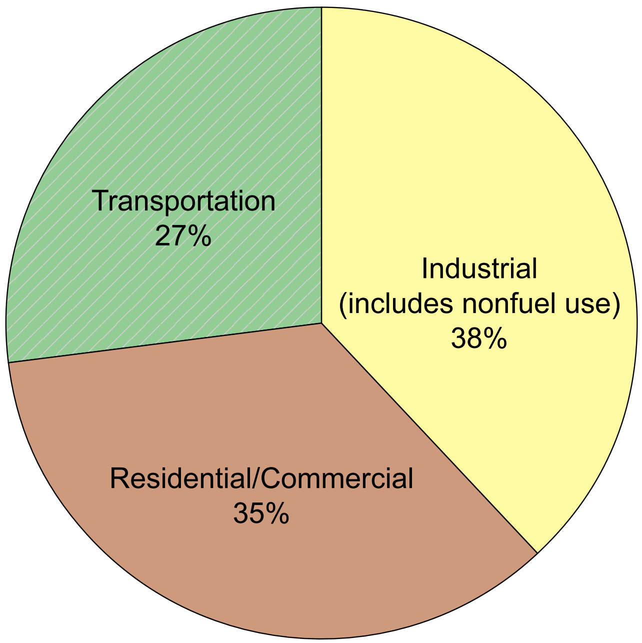


1999 Energy Consumption by Source



Source: AER99, Table 1.3

1999 Energy Consumption by End-Use Sector



Source: AER99, Table 2.1

Comparison to 1997 and 1998

For comparison, the U.S. energy flow charts for 1997 and 1998 are included in this document. The 1998 chart is in exajoules instead of quads. One quad equals 1.055 exajoules, so the numbers on the 1998 chart are about 5.5% larger than if they were given in quads.

The United States consumed 94.32 quads of energy in 1997 and 94.57 quads in 1998, an increase of only 0.25%. In 1999, however, total U.S. energy consumption was 96.60 quads, an increase of 2.1% over the previous year. (AER99, T1.1, p. 5.) As shown below in Table 1, the largest growth occurred in the transportation sector.

The numbers in the tables here are from AER99 and may have been revised since LLNL prepared the U.S. energy flow charts for 1997 and 1998.

Table 1. Energy consumption by end-use sector, 1997–1999.

	1997 (quads)	1998 (quads)	1999 (quads)	Change 1997–99
Residential/ Commercial	33.64	33.68	34.17	1.6%
Industrial (incl. non-fuel)	35.85	35.54	36.50	1.8%
Transportation	24.82	25.36	25.92	4.4%
Total consumption	94.32	94.57	96.60	2.4%

Source: AER99, T. 2.1

Energy Imports

During those same three years, the amount of energy produced in the United States remained almost constant, but the net imports increased. As Table 2 indicates, petroleum accounts for the majority of U.S. energy imports.

Table 2. U.S. energy production and imports, 1997–1999.

	1997 (quads)	1998 (quads)	1999 (quads)	Change 1997–99
U.S. production	72.532	72.550	72.523	(0.001%)
Net imports	20.94	22.51	23.10	10.3%
Net petroleum imports	19.64	20.94	20.57	4.7%

Source: AER99, T1.2 and 1.4

Resource Consumption

Variations in resource consumption can be affected by differences in supply, cost, and weather. For example, the amount of rainfall in certain regions of the United States affects the amount of hydroelectricity that can be produced. Colder winters increase the demand on fuels for space heating, while hotter summers lead to greater consumption of electricity and thus of the resources used in electricity generation.

Table 3. U.S. energy consumption by resource, 1997–1999.

	1997 (quads)	1998 (quads)	1999 (quads)	Change 1997–99
Biomass / other	3.418	3.432	3.956	15.7%
Hydro	3.940	3.552	3.417	(13.3%)
Nuclear	6.678	7.157	7.733	15.8%
Natural gas	22.530	21.921	22.096	(1.9%)
Coal*	21.490	21.660	21.756	1.2%
Petroleum & NGPL	36.266	36.934	37.706	4.0%

Source: AER99, T1.3
*Includes coal coke net imports.

Factors Affecting Consumption

Both the U.S. population and per-capita energy use have been increasing, leading to growth in overall U.S. energy consumption.

Although the U.S. Gross Domestic Product (GDP) increased steadily from 1997 to 1999, the amount of energy consumed per dollar of GDP dropped. Economic fluctuations particularly impact energy use in the industrial sector and also in the transportation sector.

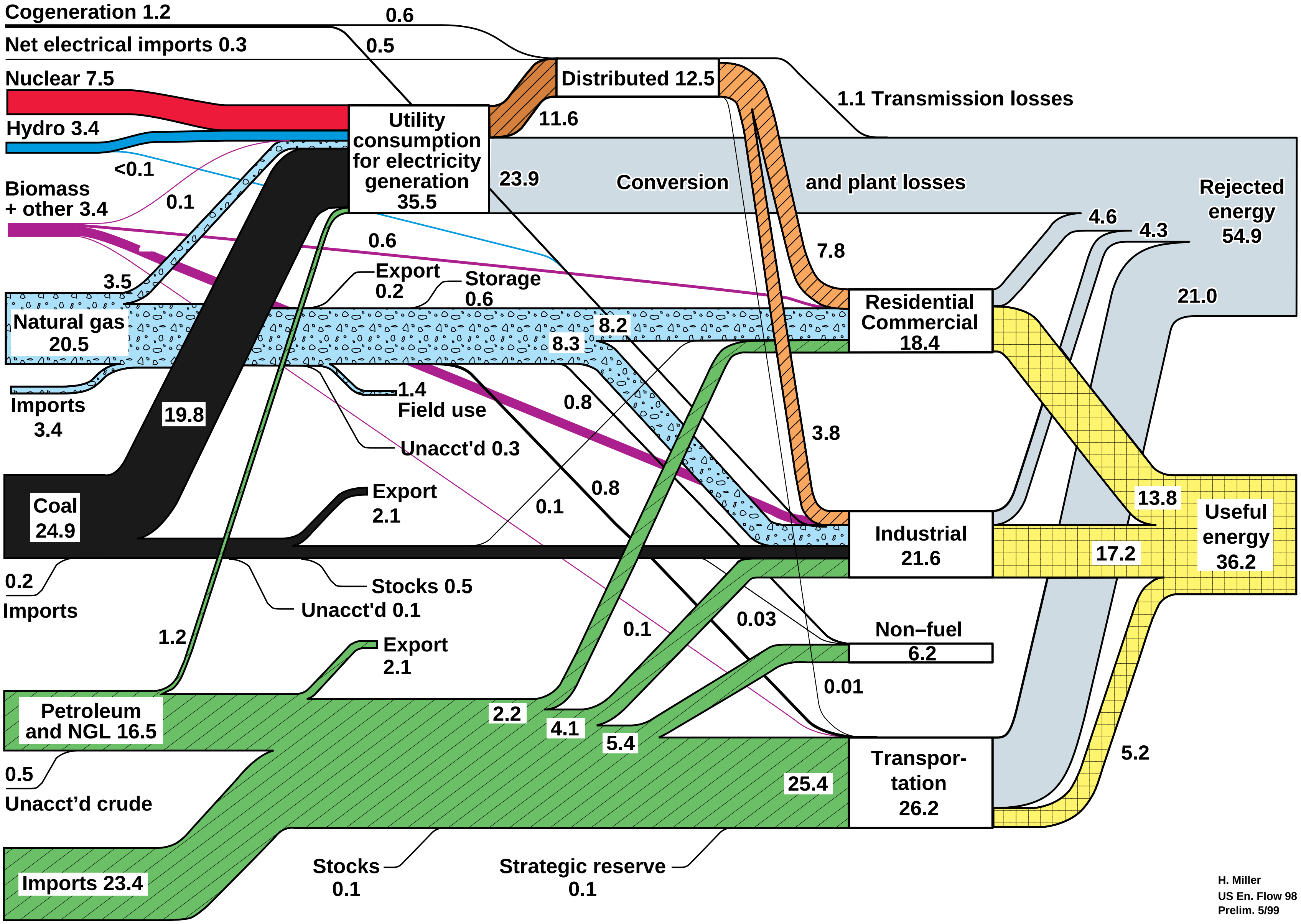
Weather conditions especially affect energy use in the residential / commercial sector. For example, the number of "heating degree days" in winter or "cooling degree days" in summer affect the demand for space heating fuels or for the electricity required for air-conditioning, respectively.

Table 4. Factors affecting U.S. energy consumption, 1997–1999.

	1997	1998	1999	Change 1997–99
U.S. population (million)	267.8	270.2	272.7	1.8%
Energy consumption per person (million Btu)	352	350	354	0.6%
GDP (billion chained 1996 dollars)	8,144.8	8,495.7	8,848.2	8.6%
Energy consumption per $ of GDP (1000 Btu per chained 1996 dollar)	11.58	11.13	10.92	(5.7%)
Total heating degree days	4,542	3,951	4,244	—
Total cooling degree days	1,156	1,410	1,228	—

Source: AER99, T1.5, 1.7, and 1.8. *Chained 1996 dollars* are a measure used to express real prices—i.e., prices adjusted to remove the effects of changes in the purchasing power of the dollar—relative to 1996. *Heating and cooling degree days* are relative measurements of outdoor air temperature. These days indicate deviations of mean daily temperature: "heating degree days" are below 65°F and "cooling degree days" are above 65°F.

U.S. Energy Flow – 1998
Net Primary Resource Consumption 100 Exajoules



H. Miller
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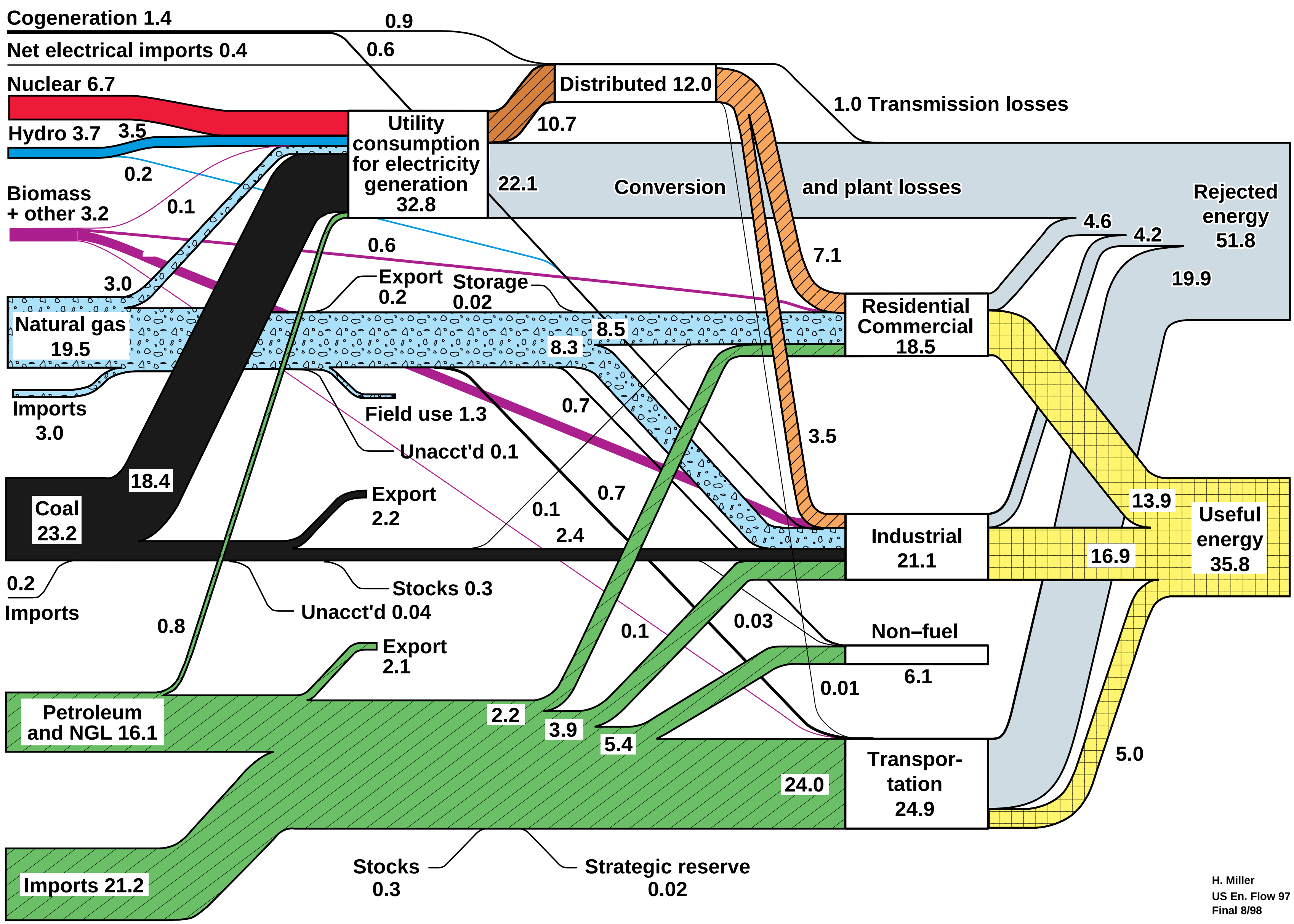
Prelim. 5/99

Other: geothermal, solar, wind, waste

U.S. Energy Flow – 1997
Net Primary Resource Consumption 94 Quads



Other: geothermal, solar, wind, waste

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US En. Flow 97
Final 8/98

Credits and Web Locations

The production and end-use data in this chart were derived from: U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1999,* DOE/EIA-0384(99), Washington, D.C., July 2000. The report is available on the Web at http://www.eia.doe.gov/aer

The U.S. energy flow charts for 1998 and 1997 were prepared by Holly Miller of Lawrence Livermore National Laboratory. The 1998 chart gives energy consumption in exajoules, the metric unit for heat. In 1998, the U.S. consumed 94.6 quads of energy, compared to 94.3 quads in 1997.

The energy flow charts prepared by Lawrence Livermore National Laboratory are available on the Web at http://energy.llnl.gov/Analysis.html

Graphic artists: Lee Dravidzius and Helen Magann

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